The Stability of Tidal Inlets

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WE ARE all familiar with the offshore bars which lie parallel to some of our coast lines, forming a long series of islands separated from each other by inlets which connect the waters of the outside sea with those of the bays and lagoons behind the islands. As these inlets frequently are used for purposes of navigation, an understanding of the factors which go to determine their size and their permanence is of great import to the engineer.

Inlets vary in size and in stability. Some of them have a tendency to shift and to migrate while others are comparatively fixed and permanent. A single severe storm may force a new inlet through the offshore bar or it may close an existing inlet. Each inlet is subjected to two opposing forces, the wind and the waves on one hand which are continually pushing sand into the inlet, and the tidal currents on the other hand which carry the sand out of the channel back into the sea or into the bay or lagoon behind the inlet. The size of the inlet and its permanency are determined by the relative strength of these two opposing forces.

The ability of the tidal currents to carry out of the channel the excess sand which may accumulate therein is largely dependent on the velocities which these currents develop at the time that the flood and the ebb discharges reach their peak values. If the inlet in question leads into a closed body of water which receives little drainage from the adjacent land, it can be assumed that the mean velocities in the channel cross-section at the peak of the flood current and of the ebb current are equal. This quantity is here represented by the letter "Vm."

In general, it can be assumed that there exists a certain critical value "Vcr" just sufficient to pick up and transport the sand in the bottom of the channel. If "Vm" is less than "Vcr," the channel will fill, while if it is greater, the channel bottom will be eroded. The value of "Vcr" varies somewhat, being largely determined by the grain size of the sand occurring in the channel. A value of about 3 feet per second can be considered as a fair approximation in most cases.

The purpose of this paper is to explain briefly the use of a certain equation which will allow us to compute the velocity "Vm" when the dimensions of the inlet and its bay, together with the tidal range of the outside sea, are known. No attempt will be made to derive the equation other than to point out that it is obtained by eliminating a single variable between two equations which have been previously derived by Colonel Earl

I. Brown in a paper entitled "Inlets on Sandy Coasts" in the Proceedings of the American Society of Civil Engineers, Vol. LIV, Part Two, February 1928. The resulting equation is simple and easy to handle and furthermore does not require the evaluation of the variable which has been eliminated.

The equations from Colonel Brown's paper are:

$$Vm = c \left(\frac{a}{2pL} \right)^{1/2} (H^2 - h^2)^{1/4} \quad (1)$$

$$M = \frac{12054}{h} \; ca \left(\frac{a}{pL} \right)^{1/2} (H^2 - h^2)^{1/4} \quad (2)$$

Vm = Mean velocity of peak tidal current in feet per second.

c = Chezy's coefficient in (feet)$^{1/2}$ per second.

a = Cross-sectional area of the channel in square feet.

p = Wetted perimeter of channel cross-section in feet.

L = Length of channel in feet.

H = Mean tidal variation of the sea in feet.

h = Mean tidal variation of the bay in feet.

M = Water surface area of bay in square feet.

These formulae assume that water entering and leaving the bay through channels other than the inlet are negligible. They also assume a simple tidal variation in the sea with a 24-hour period.

By eliminating the variable "h" between these two equations, the following equation is obtained.

$$1 = \left(\frac{12054\sqrt{2} \; a \; Vm}{H \; M} \right)^2 + \left(\frac{2pL \, Vm^2}{H \; a \; c^2} \right)^2 \quad (3)$$

where the quantities in parenthesis are dimensionless quantities. Solving for "Vm" we obtain:

$$Vm = c \left(\frac{aH}{2pL} \right)^{1/2} \left\{ (1 + r^2)^{1/2} - r \right\}^{1/2} \quad (4)$$

where

$$r = \left(\frac{12054c}{M} \right)^2 \frac{a^3}{2pHL}$$

This equation will allow us to compute "Vm" if we know the values of the variables "c," "a," "p," "L," "H" and "M." It is simple to compare the computed velocity "Vm" with the critical velocity "Vcr" and to so determine whether an inlet is self-filling, self-eroding or stationary in size. However, the word stationary as used here must not be confused with stability, as an inlet which is stationary in size in the above sense may or may not be stable.

Some light can be thrown on the problem of stability through the use of equation (4). Let us assume that "c," "L," "H" and "M" are constants and that "a" and "p" are functions of a single independent variable "x" in such a way that as "x" increases continuously from an initial value of zero, the variables "a" and "p" will increase in the same way. "Vm" then becomes a function of the single variable "x," which can conveniently be thought of as a measure of the size of the channel.

The graphs in Figures 1, 2 and 3, give an idea of how the two variables would vary. On each of the graphs the horizontal line corresponding to "Vm = Vcr" has been drawn and the intersections of this line with the "Vm" curve are points which represent inlets whose channels are stationary in size. If the line and the curve intersect as indicated in Figure 1, there are two points or roots, an unstable one at "B" and a stable one at "D." Of these, only the stable one at "D" is of course an engineering possibility. The root at "B" is unstable because any deviation from that point immediately sets into action forces which tend to further increase or aggravate the deviation. On the other hand the root at "D" is stable because any deviation from that point sets into action forces which tend to restore the channel to its initial condition.

In Figure 2 the "Vm" curve is tangent to the "Vm = Vcr" line giving rise to a single unstable root while Figure 3 represents a condition where there are no roots at all. It is obvious that under neither of these conditions would a permanent inlet be possible.

The theory just outlined can be used to determine the stability of an existing inlet, if that inlet does not have a history of sufficient length to establish its stability as a matter of observation. It also can be used in investigating possibility of improving an existing inlet or in designing an artificial one.

It may be that a new inlet has been formed across the offshore bar by storm action and that it is now desired to take whatever steps may be necessary in order to assure the permanence of the new inlet. If the "Vm" curve turns out to be one with two roots of the type indicated in Figure 1, the actual dimensions of the channel placing it somewhere on the segment "A B," it will only be necessary to dredge the channel sufficiently to place it somewhere on the segment "B C D," after which it will continue to erode itself until it reaches the stable condition represented by point "D."

If, however, it should turn out that the "Vm" curve has either a single unstable root or no root at all, it may be possible to adopt measures which will raise the whole "Vm" curve sufficiently to cause it to intersect the "Vm = Vcr" line at two separate points. The "Vm" curve can be raised in two ways; by diminishing the effective length "L" of the channnel and by altering the functional relationships which have been assumed to exist between the variable "x" and its two dependent variables "a" and "p." The effective length of the channel can sometimes be decreased by altering the alignment of the channel. It can also be decreased by either dredging the outer bar of the inlet or by constructing jetties which diminish the effective length by lowering the hydraulic resistance of the inlet.

If the "Vm" curve is to be raised by altering the functional relationships assumed between "x" and its two dependent variables "a" and "p," this must be done in such a way as to increase the value of "a" relative to that of "p." This merely means that the channel is being made deeper and narrower in order to increase its hydraulic radius and a definite limitation is imposed on what can be done in this way by the natural angle of repose of the bottom material as well as by the geometry of the cross-section which will not permit the wetted perimeter to exceed in value the quantity

$$(2\,\pi a)^{1/2}$$

It is, of course, possible, through the use of appropriate bank protection, to develop side slopes which are steeper than the natural angle of repose of the bottom material of the channel.
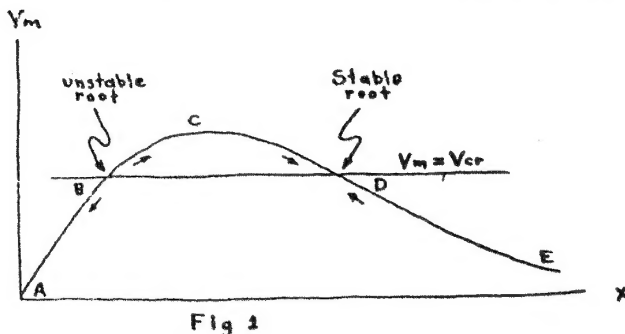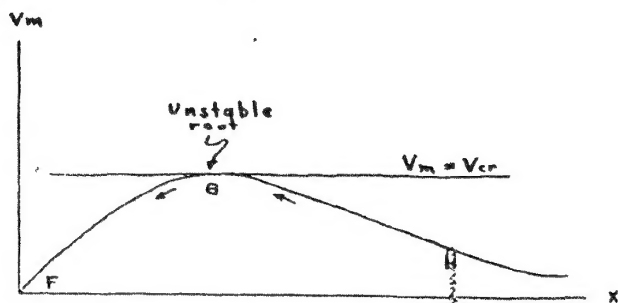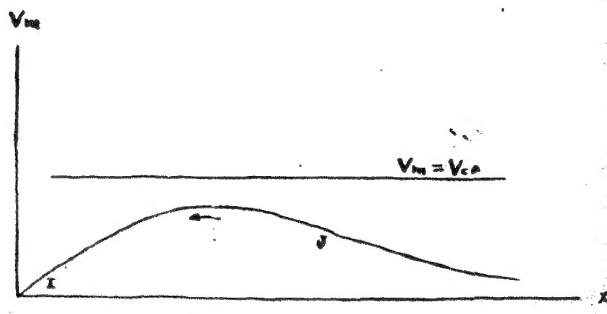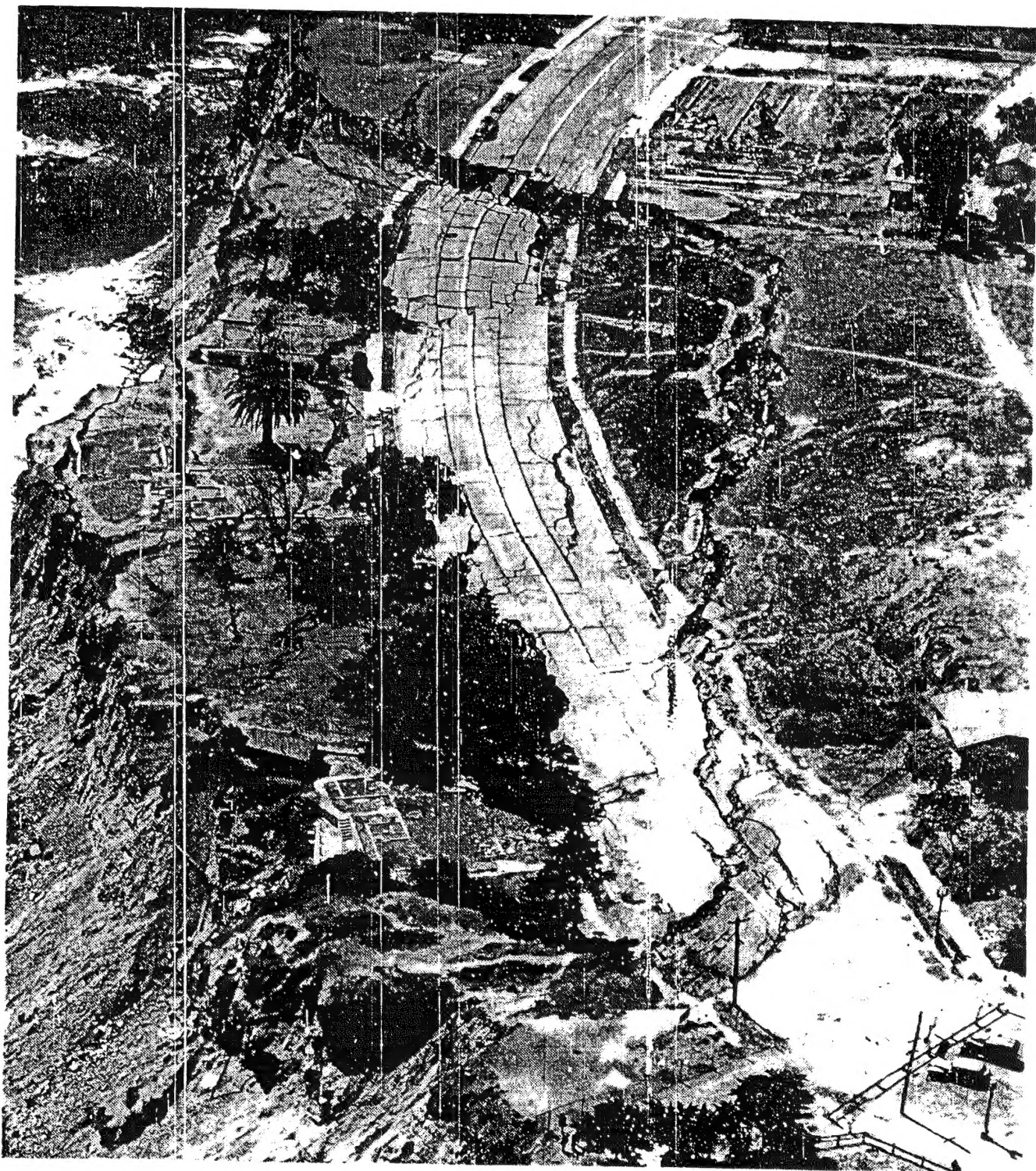

Fig 1

Fig 2

Fig 3

Shore and Beach

"Going, Going---"

Six-acre chunk of cliff at Point Fermin, San Pedro, Calif., moves slowly but relentlessly toward the sea, cracking concrete highway and causing removal of houses, whose foundations can be seen